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AUTHOR Brock, John F.
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ABSTRACT

There is little question that, over the next decade, the military services are going to be committing significant resources to developing simulators for use in maintenance training courses. The arguments for such a direction are persuasive, particularly in terms of training dollar savings. This paper reviews the past R&D on maintenance training, discusses current developments and trends, and discusses the trade-offs involved in simulating maintenance tasks. It is suggested that current maintenance training programs are only training a subset of required skills, but that introducing simulation may simply change the subset being trained. A program to avoid this problem is discussed. (Author)

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SIMULATION IN MAINTENANCE TRAINING: NOW THAT I'VE THROWN OUT THE BATH WATER, WHERE IS THE DEAR BABY?

John F. Brock
Navy Personnel Research and Development Center
San Diego, California 92152

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There is little question that, over the next decade, the military services are going to be committing significant resources to developing simulators for use in maintenance training courses. The arguments for such a direction are persuasive, particularly in terms of training dollar savings. This paper reviews the past R&D on maintenance training, discusses current developments and trends, and discusses the trade-offs involved in simulating maintenance tasks. It is suggested that current maintenance training programs are only training a subset of required skills, but that introducing simulation may simply change the subset being trained. A program to avoid this problem is discussed.

SUMMARY

SIMULATION IN MAINTENANCE TRAINING: NOW THAT I'VE THROWN OUT THE BATH WATER, WHERE IS THE DEAR BABY?

John F. Brock
Navy Personnel Research and Development Center
San Diego, California 92152

All the military services have recently shown an increased interest in the use of simulation to train maintenance tasks. A number of general purpose maintenance simulators are either on the open market now or will be within the next two years. All three services have conducted and are conducting research and development into the characteristics necessary for these simulators.

The simulation issue is a direct outgrowth of the services' renewed interest in what is variously called systems approach to training, instructional systems design, and course design procedure. The essential feature of these approaches, regardless of the acronym, is the prescription that training objectives be derived from task analysis so that students will be able to perform specific jobs upon completion of training. As training becomes more job relevant (i.e., specific to a particular cluster of job related behaviors) the use of simulation becomes more practical.

A review of the research into simulation of maintenance tasks has produced the following tentative findings: (1) if a reasonable task analysis is performed, simulation can be designed which can improve maintenance performance as well as instruction on actual equipment can; (2) the cost of using simulation for maintenance training is much less than using actual equipment for the same purpose; (3) the implementation of simulation greatly increases the potential for pedagogical interventions such as rapid feedback, cuing, and adaptive programming of instruction; and (4) in electronic and electrical maintenance training, simulation allows for safe student/system interface.

Most instructional technologists believe that an overemphasis on theory in the military's training programs of the 60's produced articulate graduates but not necessarily competent job performing graduates. With the introduction of

simulation into maintenance training programs has come a significant reduction in the amount of theory which students must learn in order to pass written tests. As the pendulum swings to the job specific training side, the implications of minimum exposure to theory need to be discussed.

It is axiomatic among instructional designers that any theory for which a student is held responsible should have a direct link to his job upon graduation. However, the course graduate is in the middle of a manpower system: the career structure and service of which he or she is a member. It is proposed that a relevant theory phase in a training program could enable the student to be better prepared for future working situations, to be better prepared to know when to ask for help from more experienced personnel, and to develop affective and attitudinal qualities which will enhance the person's overall value to the service.

There is no current system analytic technique which could automatically produce the kind of theory which would fit into the kind of training program described above. Such a technique should be developed. It is concluded that if simulation in maintenance training is to avoid being only a fad, it must be treated in the context of not only the appropriate training system, but in the context of the appropriate manpower system as well.

SIMULATION IN MAINTENANCE TRAINING: NOW THAT I'VE THROWN OUT THE BATH WATER, WHERE IS THE DEAR BABY?[1]

John F. Brock[2]
Navy Personnel Research and Development Center
San Diego, California 92152

Introduction

Two technologies are on converging paths in military training. The first is the systems approach to instructional design (Bryan and Regan, 1972); the second is the application of computer technology to training (Farr, 1972).

Called variously course design procedure, systems approach to training, or instructional systems design (ISD), the essential systems approach takes the training course developer from a set of job tasks, through the development of behavioral objectives, to the conduct of a job relevant training program (Brock and DeLong, 1975; Montemerlo and Tennyson, 1976). All the services are currently committed to some form of the ISD model (e.g., Scanland, 1974; Haverland, 1976; Ricketson, Wright, and Schultz, 1971).

A separate technology is the application of the computer to training. Since 1959, computers have evolved from the size of buildings to the size of cigarette packs or even fingernails. With the current developments in large scale integration and microprocessors, low cost instructional display and simulation systems are here in great variety (Fletcher, 1975). All three services are conducting major research and development efforts in computer-based training (e.g., Rich and Van Pelt, 1974; Rockway and Yasutake, 1974; Hurlock and Slough, 1976).

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[2]The opinions and assertions contained herein are those of the writer and are not to be construed as official or reflecting the views of the Navy Department or the naval service.

This paper will (1) discuss the state of computer-based simulation, (2) briefly review the early phases of ISD, (3) suggest that current ISD approaches are missing critical inputs, and (4) propose a research and development program which has a high probability of improving current military maintenance training.

Computer-Based Simulation

Advantages

There are several advantages to using computer-based simulation to train maintenance tasks, particularly if one is comparing simulation to the use of actual equipment for the same purpose. It is this comparison which forms the bulk of research in the area.

Cost. The first advantage is cost. For instance, Daniels and Cronin (1975) estimate a $2.4 million dollar savings in the acquisition cost of one computer-based simulator over one suite of an actual electronics system. A comparison of the life cycle costs of the two systems resulted in an additional savings of $1.3 million, simulator over actual equipment. In another study with a different device, Miller and Rockway (1975) found that the cost of two sets of actual equipment exceeded $980,000, while two complete simulation packages were available for slightly under $170,000.

Cost savings which are not as easily measured but are certainly present are those resulting from more efficient instruction and instructional management as well as better utilization of both student and instructor time. One assumption underlying the introduction of simulation into maintenance training programs is that fewer instructors and support personnel will be required; as of this writing, this assumption is not supported by data.

Reliability. There is a small but growing body of evidence that even the most sophisticated maintenance training simulators are more reliable than actual equipment in the training environment; the simulators experience much less down time (McGuirk, Pieper, and Miller, 1975; Siecko, 1975; Kanarick, 1977). The anecdotal evidence suggest that actual equipment used for training is rarely working well enough to be available for students.

Modifiability. A computer-based simulator is more easily and inexpensively modified than actual equipment. A major reconfiguration of fleet equipment will often require only software changes to the simulation system; conversely, actual equipment in the schoolhouse will require the same reconfiguration as the operational system.

Hands-on. Hands-on training is used here to imply more than just the opportunity to touch and feel equipment components. Hands-on implies the entire relevant interface the person has with the system.

This interface replication capability may be more critical to the learning process than more traditional three dimensional replications. Work at the Navy Personnel Research and Development Center (NPRDC) with the Plato IV system has produced evidence that two dimensional displays are superior for the training of some three dimensional tasks (Hurlock and Slough, 1976; Crawford and Hurlock, 1976). The point is that good simulation is at least as effective at providing hands-on training as the real equipment.

Safety. Safety is a major advantage of simulators, at least for electronics maintenance training. Instead of high power components with lethal voltage, the student can interact with very low power displays which look like and even act like the high powered counterpart.

Student Performance. In every reported study of maintenance training simulation, the test performance of students trained on the simulator has been at least equally proficient to that of students trained on actual equipment (Wright and Campbell, 1975; Hurlock and Slough, 1975; Daniels, Datta, Gardner, and Modrick, 1975). Since the computer-based simulator can adapt to student performance idiosyncracies, superior instruction should be expected. Williges and Williges (1976) have demonstrated the superiority of adaptive instruction on psychophysical skill acquisition, and adaptive strategies underlie every maintenance training simulation system with which the writer is familiar (e.g., Kanarick, 1977; Siecko, 1975; Miller and Rockway, 1975).

Instructional Options

Because of high interest in maintenance training simulation, the services have a wide range of instructional options available to them. This writer views

simulation as one strategy in an overall instructional program; it is therefore instructional delivery systems capable of simulating which are of interest to this topic.

Actual Equipment. Certainly one option which remains is the actual equipment. In electronics maintenance, actual equipment is expensive, dangerous, and represents units that could be meeting operational needs. However, some mechanical and electromechanical systems probably cost less and are more available than a simulator of the same equipment.

Mock-Up. Mock-ups with computer support have been quite successful in training operator tasks; they do not appear reasonable, however, for training maintenance tasks. Besides being expensive and unwieldy, they are built to be functionally replicable but not maintainable like the real system.

3-D/2-D. A three dimensional, two dimensional mix of display and interface components represents the leading edge of off-the-shelf maintenance training simulation systems (Daniels, Datta, Gardner, and Modrick, 1975; Piper, 1977). All instruction and as much simulation as possible is delivered over one of several computer based display systems: CRT, plasma panel, or teletype. Critical psychophysical and relational tasks are taught, practiced, and tested on three dimensional simulation displays linked to the computer and the more conventional display system. Two examples of this kind of simulation system are the Honeywell AEMT/ALQ-100 demonstration facility and the EC-3, developed by the Educational Computer Corporation.

3-D Schematic. Nearly all data on maintenance training simulation have been collected in programs using three dimensional schematics and front panel displays (Wright and Campbell, 1975; Siecko and Breslin, 1975; McGuirk, Pieper, and Miller, 1975; Miller and Rockway, 1975). The best examples of this kind of system are the EC-II, manufactured by the Educational Computer Corporation, and the Burtek Adaptive Training System, manufactured by Burtek, Inc. Essentially, these systems present operational system schematics with three dimensionalized key components; preprogrammed faults are put into the system and the student troubleshoots the system to locate the fault, receiving nearly constant feedback along the way.

2-D/Image Interface. Two dimensional displays with appropriately simulated image interfaces are best exemplified by the Plato IV graphics display (Hurlock and Slough, 1976), the General Electric Training System (Kribs, 1976), and the graphics TASKTEACH developed by Rigney and Towne (1975) at the University of Southern California. These systems can display graphics, rear projected color images, and alpha numeric information while the student responds directly on the display console with either his finger on a touch panel or with a light pen. These systems probably exploit the flexibility of the computer base the best of all extant systems.

2-D/Keyboard Interface. The most exotic systems currently being developed are included in the class of two dimensional keyboard interface systems. John Seely Brown's (1975) SOPHIE system at Bold Beranek and Newman, Inc., and Amos Freedy's and William H. Crook's (1975) Computerized Decision Training system at Perceptronics, Inc., are both artificial intelligence systems with which a student can interact in almost plain language with the computer tutor. These systems may provide the ultimate in adaptive instruction, but the current necessity of keyboard input/CRT output limits their use as a simulator.

Projected Displays. Simulation systems that haven't been looked at very closely are noninteractive projected displays: movies, tape/slide, or television. There is very sketchy and seldom reported evidence that students who simply observe particular operations from the perspective of the operator learn these operations quite well (Sitterley, 1976; Sitterley, 1974; Sitterley, Zaitzeff, and Berge, 1972). Certainly, research into using these kinds of systems for the training of maintenance tasks would be worthwhile.

Unfortunately, the current state-of-the-art of maintenance training simulators represents a heavy influence from computer technology but only limited influence from the instructional design technology. Unfortunately because a corollary of Parkinson's Law is: the need for a technology expands to the full capability of that technology. Since computer technology can produce super realistic replications of actual systems, a need for super realistic replications will be found. It is one of the suggestions of this paper that system replication as an R&D issue is no more. It is well established that systems can be replicated. The question is: Should they be?

ISD

Instruction system development (ISD) has provided a means, via task analysis, to determine precisely what it is a person does on the job. The computer-based simulation systems discussed above provide a way to train the specific behavior identified in the ISD process.

With variations not germane to this discussion, all ISD models or techniques call for a front end analysis which, at the very least, is broken into two phases: task analysis and training analysis. Montemerlo (1976) points out, and the writer believes him to be correct, that there is no generally accepted procedure for conducting a task analysis. If instructional technologists cannot agree on how to determine what a person does, it is not surprising that the process of training analysis is in complete disarray.

There are a number of approaches to training analysis, but they all seek to identify the underlying knowledge required for proficient job performance. The designer simply approaches each task with the question: what does the student have to do, in order to perform this job? Since knowledge can be stated in behavioral terms (e.g., "solves problems using Ohlms Law"), this process should eventually lead to the prerequisites with which the student should enter the instructional system (e.g., perform basic arithmetic functions).

It should be pointed out that several instructional theorists have developed category schemes and learning hierarchies which can smooth and speed this process. Gagne (1965; 1970) has articulated an eight level hierarchy of learning types; both Merrill (1971) and Markle and Tiemann (1973) have expanded the Gagne hierarchy. The writer has developed a task classification technique which, when married to the Markle and Tiemann (1973) learning category model, was very useful in developing operator training (Brock, 1976; 1977).

The Problem

The computer-based simulator systems discussed above allow for maximum pedagogical interventions. In terms of strategies, the instructional designer can completely individualize instruction, provide instantaneous feedback, establish

unlimited reinforcement schedules, and space or distribute practice. In fact, whatever is known about learning can be exploited with current, off-the-shelf systems. But knowing how to instruct is not knowing what to instruct. It is the thesis of this paper that it is the content of pedagogical interventions that raises the next issue in maintenance training research and development.

It has become axiomatic among instructional designers and researchers that military training programs are or have been overburdened with theory instruction to the detriment of performance instruction (e.g., Rundquist, 1972). The suggestion is made that until the services can derive a process for accurately determining what students need to know (i.e., be taught), device design research is of limited value. In the zeal of producing job relevant training, the services have severely reduced theoretical content in instructional programs. This theory is the bathwater of the title of this paper. In this abandoning of theory, relevant--perhaps even critical--information may be dropping out of the instructional process. It is this baby which the remainder of this paper will address.

A Proposal

Perhaps more theory that what results from a typical training analysis is needed. The military in peacetime is essentially a big training system; the schools are only a subsystem. It is suggested that a sound training analysis might well look at the underlying principles and concepts which will be needed by the course graduate beyond his immediate post training job. It has become generally accepted that across varying jobs, equipments, and even ratings, there are common elements which can be taught in a generic training program (e.g., Pearson, MacKeraghan, Stubbs, and Moore, 1974). Pearson, et al. (1974) identified commonalities horizontally across the equipment spectrum of electronic warfare maintenance personnel.

What is proposed is a vertical analysis of a career structure. Such an analysis would look beyond the immediate job of a course graduate to the population of jobs that graduate will be performing during his career. From this population should come the identification of basic skills, principles, and concepts which form the base of a particular career group.

The bathwater which needs to be thrown out is the design engineer theory which is rarely applicable to maintenance performance. The baby which may be lost is the conceptual framework for career job performance.

Once this body of theory is identified it should remain fairly constant. The long term effect should produce, among other things, technicians who will more fully understand when they are over their heads. A technician who has a grasp of the underlying principles of a system should (1) be more innovative when unique problems pop up and (2) immediately realize that he has not been trained to perform a particular operation and, therefore, to call for help.

Finally, such qualities as pride and self motivation should not be dismissed by the training designer or researcher because they lack the cleanliness of measurable behavior. Relevant theory, as discussed above, should help the young enlisted person feel more a part of his or her career category and less of a trained automon, responding to high probability stimuli with stereotype responses.

What is required, then, to restore the baby to the bath, is a program to place training analysis within the larger context of the appropriate manpower systems. Technology has given the R&D community wonderful toys; it is now incumbent upon that community to provide optimum models to use those toys.

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